# A team building approach for competency development.

Onanong Hlaoittinun, Eric Bonjour, Maryvonne Dulmet

► To cite this version:

Onanong Hlaoittinun, Eric Bonjour, Maryvonne Dulmet. A team building approach for competency development.. IEEE International Conference on Industrial Engineering and Engineering Management, IEEM'2007., Dec 2007, Singapour, Singapore. pp.1004-1008, 10.1109/IEEM.2007.4419343 . hal-00212275

HAL Id: hal-00212275

https://hal.science/hal-00212275

Submitted on 22 Jan 2008

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# A team building approach for competency development

O. Hlaoittinun, E. Bonjour, M. Dulmet
Laboratoire d'Automatique de Besançon, Université de Franche-Comté, Besançon, France

*Abstract* – **An approach for multidisciplinary team building is proposed through three steps. We suppose that tasks and team members are characterized by a set of attributes (technical competencies). First, the calculation of distance measure between task and team member (profile matching) are proposed. Second, an array-based clustering algorithm is used as an effective means for providing an alternative solution in task and team-member clustering. The proposed approach generates a systematic formation of task and team member families by sequencing the rows and the columns of a task/ team member incidence matrix. Finally, an integer programming model is formulated to solve the task assignment problem. The proposed method is demonstrated by applying it to an example in a team building problem.**

*Keywords* – **Array-based clustering algorithm, distance measure, integer mathematical programming, task assignment, team building**

## I. INTRODUCTION

The concept of multidisciplinary team building is one of the key aspects of problem solving in many product development projects. Specialists from various disciplines (e.g. micro robotics, electronics, thermodynamics, manufacturing, mechanics, image processing, optics) are gathered to develop a new product. Team building is a crucial issue in project management. Design teams are multidisciplinary groups composed of members representing many engineering disciplines. Three main elements have to be defined: task, team member and attribute. Design tasks correspond to a group of tasks to be performed in a design project. Team members from different departments possess different competencies, characterized by a set of attributes required in performing the tasks. Attributes can be viewed as soft competency or technical competency. Fig. 1 gives the global overview of our team building approach.

Furthermore, for the task assignment, we suppose that the competencies of an individual increase during task realization and can decrease with time. Therefore, task assignment implies the increase in the competency development of an individual. So, the problem of preserving an intra-domain expert is considered here in order to maintain a team member in his or her expert domain. The literature about team building does not provide the solution reinforcing the intra-domain expert competencies, or dealing with the competency dynamics.

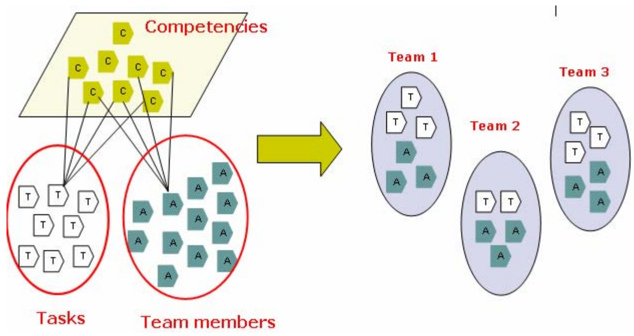


Fig. 1. Multidisciplinary team building in design project

## II. REVIEW OF RELATED LITERATURE

Numerous works about team building deal with psychological and sociological competencies (personality types, leadership, communication skills, decision-making ability etc.) [1], [2], [3]. Technical competency is the most common attribute found in team building literature in order to characterize tasks and team members [1], [4], [5], [6], [7]. De Korvin *et al.* [8], emphasized that the important factor in selecting human resources to a team are the technical competencies. These competencies will be required to implement the various activities for each phase of the project. Moreover, competencies can be considered from two points of view. First, a competency is required to carry out a task and second, a competency is possessed by one (or several) team member(s).

Boucher *et al.* [18] indicated that competencies can be seen from three distinct views: static, functional and evolutionary. This paper focuses on the functional point of view. This concerns the mechanisms of competency mobilization in a work context where the goal is to make an efficient use of available competencies.

There are various solutions to be found in the research literature. Chen and Lin [2], [9] proposed an integrated methodological framework in team member assignment. The objective of their work was to develop a framework for project task coordination and team organization from the concurrent engineering perspective in order to assign the right tasks to the right team members. In other words, it is important to know the competencies and performance levels of a team member possesses before being able to allocate tasks to him or her. Zarakian and Kusiak [4] emphasized the importance of multifunctional teams in product development. The proposed method is based on QFD and AHP method. De Korvin *et al.* [8] developed a personnel selection model for a multiple phase project. The "fuzzy compatibility" method has been used to select the potential team members for each project phase. Braha [10] presented a mathematical formulation for the problem. Two main issues are addressed by the model: 1) how to specify task dependencies, and 2) how to optimally partition the tasks between a number of teams. Gronau *et al.* [11] developed an algorithm to propose a team composition for a specific task by analyzing the knowledge and skills of the employees. This method is based on the Knowledge Modelling and Description Language (KMDL).

The clustering method presented in this paper is based on one of the array-based clustering algorithms: ROC (Rank Order Clustering). A common characteristic of this algorithm is that all the methods consecutively reorder the rows and columns according to an index until the diagonal blocks are formed. The array-based clustering approach is one of the group technology algorithms. Originally, this approach was applied in manufacturing cell formation in order to group similar part families on dedicated clusters of machines. Examples of array-based clustering algorithms are as follows: ROC (Rank Order Clustering) [12], ROC2 [13], DCA (Direct Cluster Algorithm) [14], BEA (Bond-Energy Algorithm) [15], [16]. Chu and Tsai [17] outlined a procedure for evaluating alternatives in clustering algorithms under different measuring criteria.

This paper is composed of two parts. First, we will explain our approach in team building. Second, we will illustrate our approach through a simple example.

## III. TEAM BUILDING APPROACH

Our approach comprises three main steps (Fig. 2). First, we explain how to generate a task/team member incidence matrix. Second, we present an algorithm in order to group task/team members into families using an array-based clustering algorithm. Third, we show how to solve the task assignment problem by means of an integer linear programming model. The model is based on the attributes of engineering characteristics (task/ team member incidence matrix).

1) *Generate a task/ team member incidence matrix*: The approach given here is based on incidence matrices. An incidence matrix is a matrix that shows the relationships between two classes of objects. If the first class is *X* and the second is *Y*, the matrix has one row for each element of *X* and one column for each element of *Y*. Below are the five sub-steps to this method:

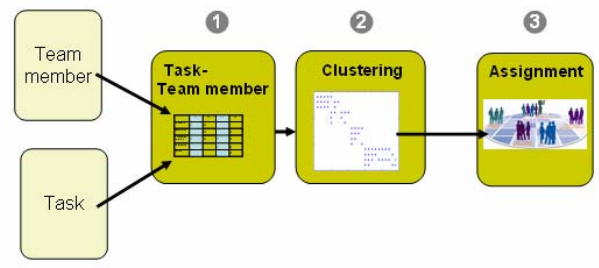


Fig. 2. Multidisciplinary team building approach

- Identify relevant attributes to characterize both task and team member. (In this paper, we consider attributes as technical competencies or disciplines).
- For each task, evaluate the demanded performance for each attribute (for instance, we obtain the task-discipline matrix (Table I))
- For each team member, evaluate the performance level for each technical competency. (for instance, we obtain the team member-discipline matrix (Table II))
- Define a compatibility indicator between task and team member (matching process).
- Generate a task/ team member incidence matrix. (see the result in Table III, we obtain the task / team member matrix)

The compatibility indicator (similarity measure) is one of the methods often used in team selection. This method finds the shortest distance between two skill sets so as to find the appropriate candidate. Numerous distance measures have been mentioned in research literature - for example, the Hamming distance used in the personnel selection [19]. What is missing in these existing measure methods is that they haven't taken into account the difference between the positive and negative gap values. The positive gap value can be viewed as an overcompetency level, and the negative gap value as an undercompetency level. Therefore, we propose a compatibility indicator as a distance measure that will be helpful to find the best correlation value between two sets of disciplines (task and team member).

Let T, D and P denote ordinary non empty sets. Let $R_1$ be a relation from T to D and let $R_2$ be a relation from D to P. Then $(R_1 \circ R_2)$ is a relation from T to P. Let us denote T={$t_{1,\dots,}\ t_p$}, D={ $d_{1,\dots,}\ d_q$}, P={$p_{1,\dots,}\ p_r$},

$R_1(t_k, d_l) = R^1_{kl}$, $\quad R_2(d_l, p_m) = R^2_{lm}$.

| | |
|---|---|
| $(R_1 \circ R_2)(t_k, p_m)$ | Compatibility indicator between the task *k* and the team member *m* |
| $R^1_{kl}$ | Level of discipline *l* required by the task *k*, |
| $R^2_{lm}$ | Level of discipline *l* acquired by the team member *m*. |

Overcompetency $(R^1_{kl} < R^2_{lm})$ indicates that the acquired discipline level of a team member is higher than the task requirement, whereas undercompetency $(R^1_{kl} > R^2_{lm})$ indicates that it is lower. For our approach, we consider only the undercompetency case and propose the following function to calculate a compatibility indicator.

$$(R_1 \circ R_2)(t_k, p_m) = 1 - \frac{\sum_{l=1}^{q} \max(0, R^1_{kl} - R^2_{lm})}{\sum_{l=1}^{q} R^1_{kl}} \qquad (1)$$

Composition value ($R_1 \circ R_2$) can be interpreted as the strength indicator of such a relational chain. It can be demonstrated that this value is included between 0 and 1.

2) *Identify task/ team member families by clustering method:* The ROC clustering algorithm will

transform the task/team member incidence matrix into task/team member families. Algorithm principle:

Step 1: For each row of the task/team member matrix, calculate the decimal weight.
Step 2: Sort rows of the matrix in decreasing order of the corresponding decimal weights.
Step 3: Repeat the preceding two steps, for each column.
Step 4: Repeat the preceding three steps until the position of each element in each row and column does not change.

A weight for each row $k$ and column $m$ is calculated as follows, where $r$ is the number of team members and $p$ is the number of tasks.

Weight for row $k$: $$\sum_{m=1}^{r} R_{km} 2^{r-m} \qquad (2)$$

Weight for column $m$: $$\sum_{k=1}^{p} R_{km} 2^{p-k} \qquad (3)$$

This array-based clustering method is simple to apply to task/team member matrices. However, it requires visual inspection of the output to determine the composition of the diagonal block formation. We adopt here the Group Density Index proposed by [5]. This index will be used to identify the potential groups after using the ROC algorithm. The variables $p'$ and $r'$ refer respectively to the number of rows and the number of columns in potential groups. The following function will be used to calculate the GDI index:

$$GDI = \frac{\sum_{k=1}^{p'} \sum_{m=1}^{r'} R_{km}}{p'r'} \qquad (4)$$

3) *Assign tasks to team members:* The task assignment contains a group of tasks (The mission requirement) to be accomplished. The mission requirement is defined here as a set of tasks $\{t_1 .. t_p\}$. The integer programming model is formulated to solve the task assignment problem.

## IV. ILLUSTRATIVE EXAMPLE

1) *Problem Formalization:* A design project with seven tasks requiring ten disciplines is used as an illustrative example. The design department has eleven members; and each member knows a set of different disciplines and related performance levels. We may consider a set of tasks, a set of team members, and a set of disciplines. The value $R^1_{kl}$ is defined as the demanded performance level of the discipline required by the task. The value $R^2_{lm}$ is defined as the performance level of the discipline possessed by the team member.

TABLE I
TASK-DISCIPLINE INCIDENCE MATRICE

| | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | D9 | D10 |
|---|---|---|---|---|---|---|---|---|---|---|
| T1 | 0,8 | 0 | 0,2 | 0 | 0 | 0,9 | 0 | 1 | 0 | 0 |
| T2 | 0 | 1 | 0,7 | 1 | 0 | 0 | 0,6 | 0 | 0,3 | ²0 |
| T3 | 0 | 0 | 0 | 0 | 0,9 | 0 | 0 | 0 | 1 | 0 |
| T4 | 1 | 0 | 0,1 | 0 | 0 | 0 | 0 | 0,7 | 0 | 0 |
| T5 | 0 | 0,8 | 0 | 1 | 0 | 0 | 0,4 | 0 | 0 | 0,1 |
| T6 | 0,2 | 0,3 | 0 | 0 | 0 | 1 | 0 | 0,8 | 0 | 0 |
| T7 | 0 | 0 | 0,1 | 0,1 | 1 | 0 | 0 | 0 | 1 | 0,7 |

TABLE II
TEAM MEMBER-DISCIPLINE INCIDENCE MATRICE

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D1 | 0,7 | 0 | 1 | 0,4 | 0 | 0,2 | 0 | 0,6 | 0 | 0,7 | 0,4 |
| D2 | 0 | 0,5 | 0 | 0,9 | 1 | 0 | 0,9 | 0,1 | 0 | 0 | 0 |
| D3 | 0 | 0 | 0,3 | 0,2 | 0,4 | 0 | 0,6 | 0 | 0 | 0,2 | 0 |
| D4 | 0,3 | 0 | 0 | 0,7 | 0,7 | 0 | 0,8 | 0,2 | 0 | 0,1 | 0 |
| D5 | 0 | 0,7 | 0 | 0 | 0 | 0,9 | 0 | 0 | 0,6 | 0 | 0,1 |
| D6 | 0,7 | 0 | 1 | 0 | 0 | 0 | 0 | 0,67 | 0 | 0,7 | 0,5 |
| D7 | 0 | 0,9 | 0 | 0,5 | 0 | 0,6 | 0 | 0 | 0,67 | 0 | 0,2 |
| D8 | 0,6 | 0 | 0,6 | 0 | 0,2 | 0 | 0,1 | 0,71 | 0 | 0,6 | 0,59 |
| D9 | 0 | 0,5 | 0 | 0 | 0 | 0,7 | 0 | 0 | 0,6 | 0,1 | 0 |
| D10 | 0 | 0,7 | 0 | 0,1 | 0 | 0,6 | 0 | 0,1 | 0,63 | 0 | 0 |

2) *Results from the clustering algorithm:* Integrating the relation $R^1_{kl}$ and $R^2_{lm}$, we will obtain the task/team member incidence matrix $R_{km}$ presented in Table III. This matrix contains the value of compatibility indicator $R_{km}$. The compatibility indicator can be interpreted as the performance level of a team member (*p)* to achieve a task (*t)*. These values are calculated from (1).

From a task/team member incidence matrix, team members and tasks will be grouped in diagonal blocks by the ROC algorithm. The algorithm furnishes three blocks separately: the first block associates five team members and three tasks; the second associates three team members and two tasks, and the third associates three team members and two tasks.

3) *Task assignment*: Considering the assignment of the team members as a binary variable, the team can be selected by minimizing the project cost. The objective is to find one suitable candidate for each task which minimizes the total salary cost of the project.

To consider the minimization of salary cost, a simple objective function is defined. The cost function depends on the individual salary multiplied by the compatibility indicator. For our hypothesis, we suppose that the lower the compatibility indicator, the longer the duration of the execution of a task– as long as the compatibility indicator is not lower than the lower bound (a).

TABLE III

TASK/ TEAM MEMBER INCIDENCE MATRIX $(R_{km} = R_{kl} \circ R_{lm})$

G1 G2 G3

| | P3 | P10 | P8 | P1 | P11 | P4 | P5 | P7 | P6 | P2 | P9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T4 | 0,94 | 0,75 | 0,72 | 0,72 | 0,55 | 0,28 | 0,17 | 0,11 | 0,11 | 0 | 0 |
| T1 | 0,86 | 0,74 | 0,68 | 0,69 | 0,51 | 0,21 | 0,14 | 0,1 | 0,07 | 0 | 0 |
| T6 | 0,78 | 0,65 | 0,73 | 0,65 | 0,56 | 0,22 | 0,22 | 0,17 | 0,09 | 0,1 | 0 |
| T2 | 0,08 | 0,11 | 0,08 | 0,08 | 0,06 | 0,5 | 0,58 | 0,64 | 0,25 | 0,4 | 0,25 |
| T5 | 0 | 0,04 | 0,17 | 0,13 | 0,09 | 0,65 | 0,65 | 0,7 | 0,22 | 0,4 | 0,22 |
| T7 | 0,03 | 0,1 | 0,07 | 0,03 | 0,03 | 0,07 | 0,07 | 0,07 | 0,76 | 0,7 | 0,63 |
| T3 | 0 | 0,05 | 0 | 0 | 0,05 | 0 | 0 | 0 | 0,84 | 0,6 | 0,63 |
| $S_p$ | 1500 | 1400 | 1450 | 1300 | 1200 | 1300 | 1270 | 1410 | 1380 | 1360 | 1300 |

For each diagonal block in Table III, to formulate the model, the following notation is introduced:

k = index for multidisciplinary tasks
m = index for team members
p = number of multidisciplinary tasks
r = number of team members
$S_m$ = salary of team members
$R_{km}$ = compatibility indicator of each couple of task and team members
$C_{km}$ = adjusting factor of each couple of task and team members. (This adjusting factor will be applied to salary rate in order to obtain a new appropriate salary value).

$$x_{km} = \begin{cases} 1 & \text{If a team member } m \text{ belongs to the team that is responsible for disciplinary task } k \\ 0 & \text{Otherwise} \end{cases}$$

The objective function of the model ((5)-(9)) minimizes the total salary cost of the multidisciplinary teams.

$$\text{Minimize: } \sum_{m=1}^{r}\sum_{k=1}^{p} c_{km} * s_m * x_{km} \quad (5)$$

Subject to constraints:

$$\forall k = 1...p; \quad \sum_{m=1}^{r} x_{km} = 1 \quad (6)$$

$$\forall m = 1...r; \quad \sum_{k=1}^{p} x_{km} \le 1 \quad (7)$$

$$\forall m = 1...r; \quad \forall k = 1...p: \quad R_{km} * x_{km} \ge 0,6 \quad (8)$$

$$\forall m = 1...r; \quad \forall k = 1...p: \quad x_{km} = 0 \ or \ 1 \quad (9)$$

Constraint (6) demonstrates that each task will be assigned to only team member.

TABLE IV

EXAMPLE RESULT

| | P3 | P10 | P8 | P1 | P11 | P4 | P5 | P7 | P6 | P2 | P9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T4 | 0 | 0 | 0 | 1 | 0 | | | | | | |
| T1 | 0 | 1 | 0 | 0 | 0 | | | | | | |
| T6 | 1 | 0 | 0 | 0 | 0 | | | | | | |
| T2 | | | | | | 0 | 0 | 1 | | | |
| T5 | | | | | | 0 | 1 | 0 | | | |
| T7 | | | | | | | | | 0 | 0 | 1 |
| T3 | | | | | | | | | 1 | 0 | 0 |

Constraint (7) demonstrates that a team member could not be allocated more than one task. Constraint (8) demonstrates that the selected team member needs to have a compatibility indicator of at least 0.6. The value of 0.6 represents the lower bound (a) of the compatibility indicator.

For each diagonal block, we obtained the following result, shown in Table IV. When the variable assignment is equal to 1, the team member is selected for the team, if the variable is equal to 0, the team member is not selected. In this example, the team member 1, 10 and 3 are selected for the team for the diagonal block I. The optimization is modeled and calculated by the optimization toolbox in Matlab.

## IV. CONCLUSION

This paper has presented a team building approach and it is illustrated through an example. This promising approach differs from the use of existing team building approaches, because it has adopted a clustering algorithm to enable tasks and team members to be grouped into families (departments). The advantage of using the clustering method in the selection process is that it allows the team members to perform tasks in order to maintain their expert domains.

Our study in team member selection can be divided into two sections. At the beginning, we presented the method for competency structuring. The solution encourages the representation of attributes in order to characterize tasks (or team members) and it encourages demonstrating the potential diagonal block of tasks and team members. In the second part, we have studied the task assignment problem in design projects. An integer programming model is formulated to solve the multidisciplinary task assignment problem.

The objective of competency structuring is to give a global image of competency to the project managers and to help them to deal with a multi-functional team building problem. In team building literature, team members belong to a functional department. But in the innovative product design, new jobs (that is, new tasks) may appear; some team members may leave or be recruited by the company. So departments may evolve. No existing method has been proposed to link task- and team- member evolution.

In this paper, some limitations should be noted, as they might lead to interesting perspectives in future research.

1) We have not considered the workload (man-hours) of team members and multi-project task assignment. .If a team member is assigned to multiple teams, the member's availability will need to be taken into account. We consider here the single-project team building. Each team member works full time for a single project.

2) In the context of competency dynamics and development, the performance level of team members will gradually increase during the project execution and continuously decrease if they are not assigned to the task corresponding to this competency for some time. The question that we might ask is: how can we apply this approach to support the global competency development of a company?

## REFERENCES


[1] E.L. Fitzpatrick, R.G. Askin, "Forming effective worker teams with multi-functional skill requirements," *Journal of Computers & Industrial Engineering*, vol. 48, pp. 593–608, 2005.

[2] S.L. Chen, L. Lin, "Modeling team member characteristics for the formation of a multifunctional team," *IEEE Transactions on Engineering Management*, vol.51, N° 2, pp.111-124, 2004.

[3] S.T. Acuna, N. Juristo, "Assigning people to roles in software projects," *Software Practice and Experience*, N°34-2004, pp 675-696.

[4] A. Zakarian, A. Kusiak, "Forming teams: an analytical approach," *IIE Transaction,* 1999.

[5] T.L. Tseng, C.C. Huang, H.W. Chu, R.R. Gung, "Novel approach to multi-functional project team formation," *International Journal of Project Management*, vol. 22, pp. 147–159, 2004.

[6] K. Hadj-Hamou, E. Caillaud, "Cooperative design : A framework for a competency-based approach," *5th International Conference on Integrated Design and Manufacturing in Mechanical Engineering*, IDMME'04, University of Bath, 2004.

[7] H-T. Tsai, H. Moskowitz, L-H. Lee, "Human resource selection for software development projects using Taguchi's parameter design," *European Journal of Operational Research*, vol. 151, 2003, pp 167-180.

[8] A. De Korvin, M.F. Shipley, R. Kleyle, "Utilizing fuzzy compatibility of skill sets for team selection in multi-phase projects," *Journal of Engineering and Technology Management*, vol 19, pp 307-319, 2002.

[9] S.J. Chen, "An Integrated Methodological Framework for Project Task Coordination and Team Organization in Concurrent Engineering," *Concurrent Engineering,* vol.13, N°3, pp. 185-197, 2005.

[10] D. Braha, "Partitioning tasks to product development teams," in *Proceedings of DETC'02 ASME 2002 International Design Engineering Technical Conferences*, Montreal, Canada, September 29-October 2, 2002.

[11] N. Gronau, J. Fröming, S. Schmid, U. Rüssbüldt, "Approach for requirement oriented team building in industrial processes," *Computers in Industry*, vol.58, N°2, pp. 179-187, 2006.

[12] J.R. King, "Machine-Component Group Formation in Group Technology," *OMEGA Journal of Management Science*, vol.8, No. 2, pp 193-199, 1980.

[13] J.R. King, V. Nakornchai, "An interactive data-clustering algorithm," *Flexible manufacturing system,* pp. 285-291, 1986.

[14] H. M. Chan, D. A. Milner, "Direct clustering algorithm for group formation in cellular manufacture," *Journal of Manufacturing Systems*, Vol 1, pp. 65-75, 1982.

[15] W. T. McCormick, P. J. Scmwitzer, and T. W. White, "Problem decomposition and data reorganization by a clustering technique ." *Operations Research*, vol. 20, p. 993-1009, 2002.

[16] K.L. Mak, Y.S.Wong, X.X. Wang, "An adaptive genetic algorithm for manufacturing cell formation," *Advance Manufacturing Technology,* pp. 491-497, 2000.

[17] C.H. Chu, C.C. Tsai, "A comparison of three array-based clustering techniques for manufacturing cell formation," *International Journal of Production Research,* 28, pp. 1417-1433, 1990.

[18] X. Boucher, E. Bonjour, B. Grabot, "Formalisation and use of competencies for industrial performance optimisation: A survey, "*Computers in Industry*, Vol. 58, Issue 2, pp. 98-117.

[19] L. Canos, V. Liern, "Some fuzzy models for human resource management," *International Journal of Technology Policy and Management*, vol. 4, n° 4, p. 291-308, 2004.